AGRONOMIC, PATHOLOGICAL AND ENTOMOLOGICAL RESEARCH ON *COFFEA ARABICA* AS A REPLACEMENT CROP FOR OPIUM POPPY IN THE HIGHLANDS OF THAILAND

PHASE II FINAL REPORT

(JUNE 1980)

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Agronomic, Pathological and Entomological Research on *Coffea arabica* as a Replacement Crop for Opium Poppy in the Highlands of Thailand

Investigations on agronomic, pathological, and entomological aspects of *Coffea arabica* were initiated in 1974. The objectives of the investigations were to introduce, evaluate, and establish arabica coffee as a replacement crop for opium poppy in the highlands of Thailand.

The first phase of the investigations was ended in June, 1977 and certain basic information on appropriate varieties, nursery management, shadings, cover crops, rejuvenation, mineral nutrition, disease and insect problems were obtained.

As the study indicated arabica coffee is being suited for the highlands and as a replacement for opium poppy, the project was extended for its second phase. Particular attention was given to variety testing and screening for rust resistance. Meanwhile, disease and insect etiology and control also received equal attention. More effort was made on problems concerning cultural practises and nutritional aspects.

I. Introduction, Evaluation and Selection of Varieties.

Introduction of arabica coffee varieties with known resistance to different physiologic races of coffee leaf rust was made in the first phase. The introduced varieties were grown in different locations with different altitudes. The first group was grown in the lowlands of Chieng Mai (350 meters above sea level) while the second group was grown in the highlands (1,200 - 1,600 meters above sea level). The objectives of the separation were to detect the presence of leaf rust incidence in all locations as well as to test the performance of the introduced varieties. Results of the testing indicated no coffee leaf rust incidence on any of the introduced varieties grown in the lowlands. Certain introduced varieties grown in the highlands developed evident leaf rust symptoms. The presence of coffee leaf rust inoculum

was then obvious in areas where arabica coffee used to be planted. These areas have been then used as testing sites for coffee leaf rust resistance of the varieties subsequently introduced. Two specific types of information namely:

(A) indentification of the physiologic races of leaf rust present in the different coffee growing areas in the highlands of Northern Thailand; and

(B) identification and screening of the varieties known to be resistant to the various Types of coffee leaf rust; were needed.

A. Identification of the physiologic races of leaf rust present in the different coffee growing areas in the highlands of Northern Thailand.

Identification of the physiologic races of leaf rust was made by the collection of diseased leaf samples from the various growing areas (Phase II, First Semi Annual Report). Uredospore samples were then collected. Both kinds of samples (diseased leaves and uredospores) were shipped to the Centro de Investigacao das Ferrugens de Cafeciro, Estacao Agronomica Nacional, Oeiras, Portugal. The following physiologic races have been identified.

	Varieties	Locations	Physiologic Race
1.	C. arabica Bourbon Type	Meajo Field Crop Experiment Station	Race II
2.	C. arabica Typica Type	Hoey Tard Chieng Dow	Races II and III
3.	C. arabica Bourbon Type	Mae-Sa-Mai Village Mae Rim	Race II
4.	C. arabica Bourbon Type	Doi Intanont	Race II
5.	C. arabica Bourbon Type	Ban Mae Lord Mae Tang	Unidentified

The physiologic race II of leaf rust is commonly present in all the coffee growing areas of the world. Since the identified physiologic races were still not representatives of all areas, more samples were to be collected and identified.

B. Identification and screening of the varieties known to be resistant to the various Types of coffee leaf rust.

Identification and screening of the varieties known to be resistant to the various Types of coffee leaf rust was made though the introduction of propagating materials from three groups of coffee growing countries namely: (1) the Latin America; (2) East Africa, Hawaii and the Oceanea; and (3) India.

1. The Latin America

Most of the introduced varieties were commercially grown varieties of the Catura and Catuai. Under the highland conditions at Nong Hoy, Mae Rim, the Catuai was found to be susceptible to leaf rust race II.

2. East Africa, Hawaii and Oceanea

The introduced varieties were known to be rust resistant to the various Types namely:

a. Rust resistant Type E.

C. arabica Villa Lobos 954. Susceptible to most strains, cold tolerant;

b. Rust resistant Type I.

C. arabica s-6 cioiccie, S-12 kaffa. Susceptible to races X and XVI

c. Rust resistant Type D.

C. arabica DK 1-6. Susceptible to races I, VIII, XII, XIV, XVI, XVII, XXIII, XXIV, partially resistant to Colletotrichum sp.

d. Rust resistant Type A.

C. arabica H-17-1, Hibrido de Timor. Resistant to all races, partially resistant to Colletotrichum sp.

e. Rust resistant Type D.

C. arabica K7 from Kenya. Resistant to race II, resistant to coffee berry disease, partially resistant to Colletotrichum sp. Large bean with acceptable quality.

3. India

Introduced varieties under this grouping were C. arabica S.795, S.947, S.952, S.333, S.645, S.288, S.1934, coorge, Kent, and coorge X Kent. The First seven varieties should be grown under shading and were resistant to races I, II and III.

In addition, F_1 and F_2 seeds of renowned parents (either in high yielding, high quality or rust resistant) were also introduced. The obtained seedlings were planted in the lowlands as well as in the highlands. This performance on vegetative growth, rust resistance, yield as well as bean quality would be observed. Parts of the obtained seedlings were artificially innoculated in the laboratory with leaf rust inoculation collected from the various coffee growing areas. Their susceptibility or resistance to any particular physiologic races of leaf rust would then be identified.

At present, results of the evaluation and selection of the introduced varieties basing on their resistance to rust, high yielding, acceptable bean quality and as being suited to the highland conditions, lead to the conclusion that;

1. Without shading: the C. arabica varieties Catura a nd Catuai are recommended.

2. With shading: the C. arabica varieties K7, DK 1-6, S.288, S.795 and S.1934 are recommended.

II. Cultural Practices.

The mortality rate of young seedlings, 1 to 2 years after being planted, has been high. Dying back of branches (usually occured in dry season) in young plants as well as in plants at yielding stages resulted in retarded growth and

development of branches into the stages ready for blooming in rainy season was not possible. Encountering of the above problems has been common among the various firms dealing with the extention of arabica coffee as an acceptable replacement crop for oppium poppy to the Hilltribes. Information concerning the following aspects are needed.

A. The appropriate kind and quality of seedlings at the time of planting.

The quality of seedlings at the time of planting is essential. Attention was made on the selection of outstanding mother plants, selective picking of ripe berries, stock seed production techniques as well as seed storage conditions in maintaining high percentage of seed viability. Particular effort was made in developing media enhancing higher rate of seed germination under the cold period (December to January) of the highlands. Burned paddy husk was found to be most suitable comparing to the other media under studied. It was observed to accumulate more radiant heat resulting in a higher temperature favorable for seed germination. The medium was also found to be rather pathogenic free and thus seed rot incidence was at the minimum. Uniform seedlings were obtained.

The seedlings have to be kept under the nursery conditions at least 12 to 16 months to become most appropriate for transplanting. Healthy seedlings are stout with un-crooked tap root and possess fairy amount of fibrous root system. Hardening of the seedlings prior to planting in the field is necessary. They must be allowed to get exposed to full sunlight two months before transplanting. Meanwhile, nitrogen fertilizer coupled with more moisture should be applied to induce more vegetative growth. Spraying program for pest control should be at 15 days interval during their period to ensure healthy seedlings. In general, 2 to 3 sprays of cupravit would be sufficient.

After being hardening, the seedlings are ready to be transplanted. Transferring of the seedlings to the planting sites could be either barerooted or kept suspended in water in a plastic bag. In case of bare-rooted, the seedlings should be at least 18 months of age with healthy stout brown stem. One precaution with the bare-rooted system is that the seedlings should be planted within 24 hours after being uprooted from the propagation plot. In so doing, more than 90% of survival rate could be achieved.

B. Land and planting hole preparation.

Selection of a growing site is of importance. Slope facing either north or east is of preference. The coffee plants will get sufficient sunlight in the morning and as the sun moves toward the west, the area will become as a ccol open shade. Slope facing south or west will get exposed to the sunlight all day long the plants are under stress due to excessive exposure. The mortality rate is usually high when the coffee plants are grown on slope facing south or west. Extra care and management are required to keep them healthy and thus the cost of production is increased.

Land clearing should be done during February to April whenever possible. Small stumps and underground root systems should be removed and burnt. Exceptional big stumps could be ignored to avoid unnecessary labor work. Big trees can be preserved at a proper distance to avoid over shading of the area. Over shading could cause low yielding even with the varieties requiring shade like S.288, S.795, S. 1934 and K7. Planting without shading is more recommended since the system gives higher yield providing that a suitable variety is available. The variety Catura is recommended.

After land clearing, preparation of the planting spots could be proceeded. Small bamboo or wood stakes (0.5 x 2 inch x 1 meter long) with one pointed and are put up at 2 x 2 meter spacing along the contour line on a medium slope. In case of high slope, the spacing between rows should be 2.5 meter along

the contour line while the spacing between plants could be retained at 2 meters. Proper preparation of planting holes is necessary to provide the seedlings a good start. The size of the planting hole should be 50 x 50 x 50 cm. The toploil and subsoil should be separated from each other and let the planting holes be exposed to the sunlight for at least on month. At the time of planting (usually in May), the topsoil well mixed with animal manure or composed manure (approximately 3 kilograms). An amount of 16 - 20 - 0 chemical fertilizer (approximately 20 g) is also added. The planting hole is then filled with the well mixed topsoil with moderate compaction. The subsoil is evenly distributed around the planting hole and the same bamboo or wood stake is put back. The planting hole is then ready for planting at the proper planting date.

C. Appropriate time of planting.

Usually, June is the appropriate time of planting for coffee in the highlands since the rain occurence starts. In certain locations, planting could be done before June due to earlier rain occurences. Planting should be no later than June to provide the seedlings ample time to grown before the dry season commences. Late planting would result in high rate of mortality due to the shallow root system being subjected to low soil moisture content.

Planting date can be decided by the soil moisture content. When the soil at the depth of 50 cm. is observed to be moist, it is proper time for planting. After planting, be sure to press the soil around the seedling stem to make good contact between the root system and the soil. Being of neglected the air pocket exists and the seedlings could subject to drought as the rain occurences cease.

D. Care and management of young seedlings after being planted in the first year.

Without shading, special care and management is require after planting. It becomes more crucial if the seedlings were transferred bare rooted to the planting site. Make sure that the root systems are in good contract with the soil and the pressing of the soil around the seedling stem is not neglected. The seedlings should be tired to the bamboo stakes to present vibration from wind blown. Weeding around the plenty area is necessary to prevent competition for moisture, nutrients and light between the seedlings and weeds.

E. Fertilizer application and spray program for pest control in young seedlings.

After weeding, chemicial fertilizer (16 - 20 - 0) at the rate of 20 g/plant would be applied. Being broadcasted, the fertilizer should be well into the soil to prevent lost by leaching and evaporation another application of fertilizer should be made in October to supply the plants with sufficient nutrients before the rain stops. Mulching with rice straw or dried plant residuals is necessary to preserved moisture around the root system in the dry season. Being neglected, dying back would occur and root rot will be encountered in the next rainy season.

spraying of chemical for pest control should also be done at the time of fertilizer application. One or two through sprayings of cupravit at the rate of 40 g/20 L of water will be sufficient in planting locations when leaf rust incidence has never been observes. Spraying of the chemical on a rain free day at one month inteval is necessary in planting locations when leaf rust incedence in severe.

F. Varietal and pruning trial.

Proper pruning of the coffee plants could increase coffee yield as well as their longevity. Each pruning system has its own merit providing that the system has been practiscal

under the appropriate conditions. Meanwhile, a practical pruning may be more suitable to a particular pruning system than the other. The objectives of the study were to determine the most approprivate pruning system adapted to the highland conditions of Northern Thailand.

Results of the study indicated that the multiple stem of pruning system proved to be superior to the single stem system. All of the varieties under studied adapted best to the multiple stem pruning system especially with the variety C. arabica K7

G. Rejuvenation of declined plantation

Cause of the decline and lack of yield were due to the infestation of coffee pests, the lack of proper attention to the cultivation as well as frost injury. Coffee plants of over 12 years of age tended to decrease in yield and needed to be rejuvenated.

Rejuvenation of a declined plantation could be made effectively providing that reasonable care and mangement (fertilizer application and pest control) were practiced. The rejuvenated trees would flower and yield berries within two years after cuttingback. Better response was observed with the bourbon type of Arabica coffee rather than with the typica type. The bourbon type would recover sooner with a lower percentage of mortality. Development of the new shoots was more numerous with the bourbon type.

III Pathological Aspects

Three main disease problems namely : Coffee leaf rust; Berry diseases; Brown eyespot; have been found on arabica coffee grown in the Highlands of Northern Thailand.

A. Coffee leaf rust

Coffee leaf rust caused by Hemileia vastatrix B.&Br. is the most serious problems encountered in the coffee growing areas in the highlands. Particular attention has been paid on this problem and the following aspects of the disease have been studied.

1. Study on the effectivers of certain chemicals against arabica coffee leaf rust.
2. Laboratory studies of the Hemileia vastatrix B.&Br.
3. Race differentiation of coffee leaf rust.
4. Study on the artificial inoculation of the Hemileia vastatrix to Coffea arabica and
5. Varietal reaction of coffea arabica L. to leaf rust (Hemileia vastatrix B.&Br.)

1. Study on the effectiviness of certain chemicals against arabica coffee leaf rust.

Study on this aspect of the problem was initiated in 1975 and has been carried on till 1978. The effectiveness of the following chemicals against arabica coffee leaf rust was studied.

a. Pyracarbolid 50 w.p. (Sicarol)
b. Copper oxychloride 86 % (Cupravit)
c. Oxycarboxin (Plantvax)
d. Triadimefon (Bayleton)

The systemic type which includes Pyracarbolid, (15 g/20 l), Triadimefon (12 g/20 l),and Oxycarboxin (60-70 ml/20 l)are very effective controlling coffee leaf rust. The first spray should be made in early June. The total number of spraying is 4 to 5 times during the rainy season at 4 to 5 week interval.

The copper oxychloride (cupravit) at the rate of 60 to 80 g/20l gives satisfactory control of the leaf rust. The first spray should be made in May and the total number of spraying is 5 to 6 times during the rainy season. The interval of spraying is 4 weeks.

2. Laboratory studies of the Hemiliea vastatrix B.&Br.

Details of the studies can be referred to in the phase I Fourth Semi-Annual Report (January - June, 1976). The objectives were to obtain information leading to the efficient control measures of coffee leaf rust disease applicable to the highland conditions of Northern Thailand. The studies included morphological aspect of the disease and the effect of age of mycelium on spore viability. Study under laboratory conditions showed that wind of relatively high velocity failed to dislodge spores from mature rust pustules. Their natural adhesion was readily broken down by water and thus rain splash could play an important role in the dispersal of uredospores.

3. Race differentiation of coffee leaf rust.

Information leading to the efficient control measures of coffee leaf rust disease are available in various foreign literatures. However, the available information may be useful to those countries where the information were obtained but may not be applicable to the highland conditions of Thailand. Races differentiation of the local coffee leaf rust disease is then essential for effective control of the disease.

At the Centro de Investigacas das Ferrugens de Cafeciro, Estacao Agronomica diacional, Oeiras, Portugal, more than 30 physiologic races of Hemileia vastatrix have been identified. It is believed that in Thailand the organism may also have many races. In case that the races of the fungus in endermic area identified, the introduction of the resistant varieties of coffee to the specific races can be made and thus the goals to establish arabica coffee as a replacement crop for opium poppy in the highlands as well as other regions of Thailand can be fulfilled.

In 1978 each sample of five disensed leaf of Coffee arabica L. were collected from five growing areas in the North and two samples of Coffea canephora were collected from the south. Identification of the physiologic races of the samples was made in

Portugal. Results of the identification revealed that all the samples were infected by physiologic race II of leaf rust with one exception of the sample collection from Hoey Tark, Chiang Daw that physiologic race III was also identified.

Another shipment of five disease leaf samples to Portugal was made in 1979 for further identification of the physiologic races of leaf rust. Unfortunately, the result has never come out.

Identification of the physiologic races of leaf rust present under the highland conditions of Northern Thailand is an essential key to efficient control measures of the disease. However, a waiting for the results from Portugal is time consuming and causes delay to other studies. Identification of the physiologic races could be accelerated if the project could make access of the 24 differential clones necessary for the identification.

4. Study on the artificial inoculation of the Hemileia vastatrix to Coffea arabica

The objectives of the artificial inoculation of the Hemileia vastatrix to coffee seedlings in the laboratory were to develop techniques that could identify rust resistant clones in the laboratory and thus time and effort could be saved tremendously.

Relults of the study indicated that the developed techniques is reliable and could be used effectively in identifying resistant clones providing that susceptible check varieties are available. It is fortunate that C. arabica Mae Lord and T. 980 were found to be very susceptible to the artificial inoculation and could serve the purpose well. The ideal conditions for the artificial inoculation include 91 to 92 % relative humidity at 21 to 24°c. Inoculation should be made after work since light has tremendous effect on the germination of the spores.

5. Varietal reaction of Coffea arabica L. to leaf rust (Hemileia vastatrix B & Br.)

Twenty eight varieties of hybrid crosses introduced from Portugal plus seven locally grown varieties were grown at Ban Mae Lord where severe rust disease incidence has been reproted. They are F_1 and F_2 hybrid of known resistance to various physiologic races of leaf rust. Berries from these plants with outstanding performance were collected. The seeds were germinated and half of the obtained seedlings were test by the artificial inoculation for their rust resistance. Detail of the study can be referred to in the Phase II Fifth Semi - Annual Report.

Artificial inoculation of the offsprings of H. 528/25, H 285/23 and most of the H.528/46 with uredospore suspension not revealed any infection symptoms under the controlled environments. Meanwhile, off-springs of the H.306/1 and H.589 all showed infection symptoms three weeks after being inoculated. The varieties Mae Lord T.980 were used as susceptible checks. All of the seedlings showing no infection symptoms under the artificial inoculation were planted at Ban Mae-Lord and Ban Pa-Mieng. The future offsprings of these plants will be F_4 offsprings still show resistance to the future artificial inoculation test.

Another set of seedlings (1,820 plants germinated from 114 mother plants of 30 hybrid lines grown at Ban Mae-Lord, Mae-Sa-Mai and Ban Nong-Hoy) were tested for their rust resistance by the artificial inoculation in 1980. The number of seedlings from each mother plant ranged from 7 to 34 plants. The varieties Mae-Lord and T.980 were still used as the susceptible checks. Results of the test could be categorized into four groups.

Group I

Consisted of seedlings with 100 % of resistance to the artificial inoculation test. The total number of seedlings was 591 plants from 39 mother plants of 19 hybrid lines.

H.285/23 NH.1, H.285/23 NH.6, H.285/23 NH.7, H.285/55 NH.4,
H.285/55 NH.7, H.361/3 ML.1/3, H.361/3 ML.2/6 H.361/3 ML.2/8,
H.361/3 NH.3, H.361/3 MS.1, H.361/3 MS.2, H.373/24 ML.2/9
H.373/46 ML.1/5, H.373/46 NH.9, H.377/8 ML.1/1, H.377/8 ML.1/6,
H.377/8 NH.6 H.377/8 MS.1, H.398/6 ML.1/7 H.398/6 ML.2/8,
H.420/9 ML.1/2 H.420/9 ML.1/6, H.420/9 ML.2/1, H.420/9 NH.7,
H.459/16 NH.7, H.496/52 NH.1, H.496/52 MS.1, H.528/21 MS.8,
H.528/46 NH.5, H.528/49 NH.[illegible], H.528/49 NH.5, H.589 ML.1/5,
H.W.26/7 NH.1, H.W.26/7 NH.9, H.W.26/7 NH.10, H.W.26/13-19 NH.1,
S.134, S.795 and S.947

Group II

Consisted of seedlings with 90 to 99 % of resistance to the artificial inoculation test. The total number of seedlings was 262 plants from 18 mother plants of 12 hybrid lines.

H.285/23 NH.3, H.285/55 NH.3, H.361/3 ML.1/7, H.373/24 ML.2/10
H.285/23 NH.3, H.377/8 ML.2/2, H.420/9 ML.1/1, H.420/9 ML.1/4,
H.420/9 ML.1/7, H.420/9 ML.1/9, H.495/16 NH.1, H.473/13 ML.1/5,
H.473/13 ML.2/6 H.496/52 NH.2, H.528/18 ML.1/1, H.528/18 ML.2/2,
H.528/46 NH.1, S.333 and S.645

Group III

Consisted of seedlings with 80 to 89 % of resistance to the artificial inoculation test. The total number of seedlings was 380 plants from 26 mother plants of 15 hybrid lines.

H.285/23 ML.1/5, H.285/23 NH.5, H.373/24 ML.2/1, H.373 ML.2/8,
H.373/46 NH.3, H.373/46 NH.4, H.377/8 ML.1/2, H.377/8 ML.2/3,
H.377/8 ML.2/4 H.377/8 ML.2/6 H.420/9 NH.1, H.473/13 ML.1/2
H.473/13 NH.8, H.496/52 NH.4, H.528/18 ML.1/8, H.528/18 ML.2/1,
H.528/18 ML.2/4, H.528/25 ML.1/8 H.528/46 NH.3, H.528/49 NH.2,
H.589 NH.2, H.589 NH.9, HW.26/7 ML.2/1, H.W.26/7 NH.7,
S.288, and S.952

Group IV

Consisted of seedlings with resistance under 80 % to zero resistance. Seedlings under Group I, Group II and Group III were transplanted into the fields at different growing sites in the highlands of Northern Thailand. Offsprings of these plants will be tested for their rust resistance. Those with possitive rosults will be released as resistant varieties specifically adapted to the highland conditions of Northern Thailand. Seedlings under Group IV were excluded.

B. Berry disease.

Berry diseases cause by Colletotrichum coffeanum Noack. and Colletotrichum gloeosporioides Penz. rank second from coffee leaf rust in causing serious damages to the coffee growing industry in the highlands of Northern Thailand. Survey data of the berry disease incidence indicated serious problems for future production of arabica coffee either on lowlands or in the highlands. Studies on the symptomology, their spread as well as morphology and taxonomy were reported in the Phase I, Fourth Semi-Annual Report, January-June, 1976.

Control measures by chemical sprays were conducted in 1981. The following chemicals were included in the study entitle "Effectiveness of certain chemicals against arabica coffee berry diseases".

1. Captafol 60 % W.P. at the rate of 30 g/2o L water.
2. Carbendazim 60 % W.P. at the rate of 8 g/20 L water.
3. Copper Oxychloride 85 % W.P. at the rate of 80 g/L water.

Four sprayings of each of the chemicals were made in June. July, August and October. Evaluation of the results will be made during November - December, 1981. Confermation of the results will be conducted in the successive year.

C. Brown eye spot.

Brown eye spot causes by Cereospora coffeicala Berck. and cooke. is common in all the arabica coffee growing areas in the highlands of Northern Thailand. The disease causes no significant effect on mature plants. However, Brown eye spot can cause serious damages to the seedlings in the propagation plants. The effect is more intense with those under poor care and management. The disease can be most serious with these seedlings grown without shading, over exposed to sunlight and the amount of soil nitrogen is lacking. Studies on the symptomology, its spread and other aspects of the disease were reported in the Phase I, Fouth Semi - Annual Report.

Chemical control measure of the brown eye spot at seedlings stages was studied. Copper Oxychloride and Pyracarbolid at the respective rates of 72 and 12 g/20 liters of water, were found to be most efficient in the control of the disease after two to three times of spraying. Good care and management of the propagation plot will reduce the disease incidence to the minimum.

IV. Entomological Aspects.

Survey on the species, bionomics and distribution of insect pests of arabica coffee grown in the highlands of Northern Thailand was undertaken. Fifteen species of insect pests were found feeding on coffee crops grown in the various plantations. List of the major insect pests which can cause serious damages to the coffee growing industry in presented in the following Table.

Major insect pests of arabica coffee found in the highlands of Northern Thailand.

Common Names	Scientific Names	Family	Order
Mealy bug	Pseudococcus sp.	Pseudococcus	Homoptera
Black aphids	Toxoptera aurantii, Fonse.	Aphididae	Homoptera
Green scale	Coccus viridis, Green.	Coccidae	Homoptera
Citrus leaf - roller	Archips micaceana, Wkv.	Tortricidae	Lepidsptera
Red coffee borer	Zeuzera coffeae, Nietw.	Cossidae	Lepidoptera
Bark eating insect	Unknown	Cerambycidae	Coleoptera
Coffee berry borer	Hypothenemus hampei, Few.	Scolytidae	Coleoptera

Classification, bionomic and distribution of these major insect pests were studied in details. Chemical control measures were also studied. At present, results of the chemical control studies have been put in the plant protection program recommended to areas where arabica coffee is to be substituted for the opium poppy.

A. Mealy bug (Pseudococcus sp.)

Mealy bug is sucking insect commonly found on coffee seedlings propagated in the nursery. The damages caused by this insect are on those young portions, tender stems and new developed leaves. The infested parts become malformed and growth of the seedlings is much retarded. The outbreak of the mealy bug is usually more intense during the dry season especially when water is lacking.

Physical control through the even supply of water during the dry season is always effective. Chemical control is more effective with the systemic type of chemicals. Monocrotophos and Dimethoate at the rate of 0.05 % active ingredient are recommended. The first spray of the chemical should be made at the first observation of the presence of the pest. The spray is repeated at 7 to 10 day interval until clean. Spraying program at monthly interval thereafter would be sufficient to keep the seedlings free from mealy bugs.

B. Black aphid (Toxoptera aurantii, Fonse.)

Black aphid is another serious sucking insect found feeding on arabica coffee grown in the highlands. The presence of Black aphid can be observed at every flush of young leaves. The infested young portions of tender stems and new developed leaves will become malformed and growth of the plants is much retarded.

Since Black aphid is sucking insects, systemic insecticides are recommeded for its control. Oxydemetan-methyl, Monocrotophos or Dimethoate at the rate of 0.05 % active ingredient give satisfactory control of the pest. The spray program should be at 7 to 10 day-interval after the first sign of presence until clean.

C. Green scale (Coccus virids Green.)

Among the sucking insects found feeding on arabica coffee, Green scale is considered as the most troublesome. Its infestation is found in all the coffee growing areas of the North. Malformation of the young developed organs (leaf curl, misshaped) coupled with retarded growth are the reslts of the infestation. Long persistence of stunted growth is usually observed after each heavy infestation and dying back of small plants is inevitable. New transplanted seedlings of 1 to $1\frac{1}{2}$ years of age are most likely to be infested by the pest.

Systemic insecticides are recommended for its control. The use of Monocrotophos or Dimethoate at the rate of 0.05 % active ingredient at 7 to 10 day-interval is practical in areas where water supply is abundant and the growing sites are of medium slope. In care of high sloping and water supply is lacking, the use of systemic chemical in granular form is more practical with effective control.

Granular systemic insecticides as Furadan 3 G or Temik 10G at the rate of 1 g (a.i) per plant give effective control of Green scale when the chemical is broadcasted around the plant within 30 cm of radius from stem base. Since sufficient soil moisture should be maintaine ofter the application of the chemical to insure best results, the use of granular systemic insecticides is most appropriate in early rainy season.

D. Citrus leaf roller (Archips micaceana Wkr.)

The scientific name of Citrus leaf roller used to be Cacoecia micaceana kr. Despite the occasional infestation of Citrus leaf roller on coffee seedlings in the nursery, it should be considered as serious pest. If neglected, swift damages to the leaves of the seedlings could occur. Either rolling of single young leaf or attaching of two young leaves together with their spindled web is the first process of infestation. The insect then lives in the rolls and feeds on the young leaves. After feeding, the insect leaves the old rolls and proceededfor the new ones.

Effective control of the pest is through the use of Azodrin 56 % E.C. or Tamaron 50 % E.C. at the respective rates of 0.05 and 0.08 % active ingredient at & to 10 day-interval at the first sign of presence until clean.

E. Red coffee borer (Zeuzera coffeae Nietn.)

Red coffee borer is stem borer causing 1 to 7 % of damages to the coffee plants. The larvae bore into stems and branches of coffee plants and feed in there. Tunneling made into the stems and branches is the cause of dying back of the upper portions of the trees down to the point of infestation. In many cases, the dieback portions toppled down and the stumps sent out new shoots. Small coffee plants could be totally killed by the pest.

Control of the pest is rather difficult since the larvae are not expose to the spray chemical. Vigilance coupled with chemical treatment and proper cultural practices can keep the damages under the economic threshhold. The following control measures have been recommended in the plant protection program.

1. Elimination of favored host plants
2. Keep the growing area clean and frequent inspection of the trees to locate the presence of the insect.
3. Prune away the infested branches beyond the tunnelling of the borers and burn them up.

4. Use of light traps to trap the adult months at night during the breeding season.
5. Use of paradichlorobenzene as a fumigating agent. Plugging of the hole of borer with small cotton wad soaked with paradichlorobenzene is effective.
6. Use of chlorinated hydrocarbon insecticides. Three to four applications of the chemical per year on the trees will be sufficient.

F. Bark eating insect (Species unknown)

Bark eating insect is quite a threat to the coffee growing industry since its mode of infestation causes cambium tissue destruction. The infested plants are under severe shortage of water and nutrients and finally die. The damage is of more economic importance when it occurs to grown up plants of heavy yielding potential. The insect responsible for the damages has never been trapped.

Vigilance and good cultural practices similar to those mentioned with the red coffee borer are necessary. Chlorinated hydrocarbon insecticides are also recommended. The application could be either soil treatment or direct treatment onto the bark at 10 to 12 inches of height above ground level. Two to three applications of the chemicals per year would be sufficient. Since the chlorinated hydrocarbon insecticides have long residual effects, the use of these chemicals should be with great precaution to avoid unexpected **ccnfamination** of the environment.

G. Coffee bean borer (Hypothenemus hampei Ferr.)

Coffee bean borer is of high economic importance. At present, the pest has been found in all the growing areas of the world. In Thailand, the spread of the pest has been reported in the southern most region as well as in the northern most region of the country.

The adults of the borers as well as the nymphs will bore in the coffee berries and feed on the coffee beans. Either both beans or one of them will be damaged relulting in the decay of the berries, malform, dieback, and senescence of the berries. The infestation can happen in the propagation seed storage causing poor germination of the seeds or no germination at all. In serious cases, the damages could be up to 87 %. In general, when 50 % of the berries have been infested, the damage of the beans would exceed 25 %. The infested berries will be graded as low in quality and dropping of the berries usually occurs.

Since the coffee beans are used for human consumption, great precaution has to be made on the use of chemicals for control measures. One interesting infestation pattern was observed with the diminishing of the incidence as the distance from the dense shade increased. The average incidence under the first ten meters from the dense shade is 47.7 percent while the incidence decreased to 25.3 and 18.9 percent as the respective distances increased to 20 and 30 meters. Infestation incidence as high as 94.02 percent was observed in the plot with dense shade while the incidence in the plot without shade was 30.63 percent. The growing of coffee without shading is quite recommended to reduce coffee berry borers. Nevertheless, the following measures have to be practised.

1. Over shading of the plantation should be avoided. Proper pruning of the trees coupled with vigilance of the planting areas will be helpful.
2. Left-over of the dry berries on the tree is prohibited.
3. Ellimination of all the drop-off berries under the bushes through burning is recommended.
4. Mass growing of the same variety to avoid un-uniform blooming and berry setting. This would aid in a more effective pest control as well as harvestation of the ripen berries.
5. Direct exposure of the beans to sunlight for several times would be able to stop the growth and spreading of the borers already presented in the beans.

Short residue insecticides are more preferable for chemical control of the pest. Malathion and Carbaryl at the respective rates of 0.1 and 0.08 % active ingredient give effective control of the pest. The spray program should be at 15 day-interval for 3 to 4 applications throughout the berry bearing period. The first spraying should be made when the berries are approximately 0.5 mm. in diameter. Despite of their short residual, both chemicals should be sprayed at least two week prior to harvestation of the berries.

V. Mineral Nutrition Aspects

Studies on the mineral nutrition aspectes of arabica coffee grown in the highlands of Northern Thailand were initiated in 1975. Since studies of these aspects have never been done elsewhere in Thailand, all the works carried out during the period of this project have been fundamental. Relults of the studies can be used as guide lines in the extension of arabica coffee as replacement crop for opium poppy in the highlands. Meanwhile, the results can be used as basic information for future works. The following aspects of mineral nutrition were under taken during the period of 1875 through 1981.

A. Soil Survey and Soil analysis

Survey of topography as well as the fertility level of the soils of various coffee growing locations was undertaken. Soil samples from the various coffee growing areas were taken and analysed for the chemical constituents. The obtained infromation were used in the planning of subsequent researches.

The topography of most of the coffee growing areas in the highlands are sloping areas. The slope ranges from 10 to 40 percent. Mixed cultivation of coffee and some other vegetation is a common practice among the various Hilltribe. The size of the cultivation ranges from 2 to 5 rai per family. Most of the soils in the growing areas are light lixture with good drainage. The soil reaction ranges from 5.0 to 6.5 with medium amount of organic matters

in the top soils (3 to 5 % OM). The amount of organic matters usually decreases as the depth of the soils increases. The amount of available phosphorus is usually low. The lowest figure can be down to 3 ppm. in many areas while the highest is around 20 ppm. The amount of exchangeable potassium is medium and moving towards the high range. The figure of 100 ppm. K_2O or higher is commonly found in many areas. The existance of most secondary nutrients are subficient.

B. Mineral contituents of Coffea arabica leaves.

Preliminary study on the amount of mineral contituents of arabica coffee leaves was undertaken. Leaf samples were taken during January (cool going on dry season), May (early rainy season) and September (late rainy season). The amount of nitrogen was low in cool-going on dry season. The amount increased as the rain commenced in May and decreased again as the rain occurences stoped. Phosphorus was lower than the optimum levels in cool-going on dry season and become optimum during the rainy season. Potassium was lower than the optimum levels throughout the year. The rest of the nutrient elements were at a satisfactory level.

Analysis of the leaf samples taken from the experimental plots treated with the various treatments of chemical fertilizers and manure was made. The constituents of most elements were close to the optimum levels or being higher. Uptake of the nutrients was correlated to the amount and kind of the applied chemicals. Higher application of nitrogen relulted in higher amount of nitrogen in the leaves. A trend of decrease was observed when nitrogen application was coupled with phosphorus. Nevertheless, increase amount of nitrogen was observed as higher rates of nitrogen were applied with phosphate treatment. The amount of leaf phosphorus was positively correlated with the amount of the phosphate applied to the soils. Negative correlation was observed when phosphate and nitrogen were applied together. The amount of leaf potassium decreased as the amount of soil nitrogen

and correlated with the amount of soil nitrogen. Increased soil nitrogen will reduce the calcium and magnesium content of the leaves.

C. Study on the probable cause of leaf deficiency symptoms in Coffea arabica.

Certain deficiency symptoms have been observed on some coffee seedlings growing in the nurseries as well as after transplanting. Some healthy looking stands have also been observed to later develop similar symptoms. Similar symptoms were also observed on coffee trees grown by hilltribe people in many locations. The general symptoms are leaf chlorosis with netted green veins. In severe cases, rosette of small and malformed leaves developed and the plants became stunted. In case of mature trees at bearing stage, yield will be significantly decreased. Results from two year expriment confirmed the symptoms as zinc deficiency. Zinc either in sulfate or chelating forms were found to give satisfactory results. The rate of application was 20 g/20 liters of water at 15 to 30 day-interval four to six applications per year.

D. Study on the effect of two chemical fertilizers, N, P, and manure on Coffea arabica.

Since soil analysis of many of the soil samples revealed excessively low amount of phosphorus, good growth and high yield of coffee plants grown in such soils can not be anticipated. In addition, to make use of the abundant amount of farm manure available in the highlands, chemical fertilezers, N, P, and cow manure were included in the experiment.

The objectives of the study were to determine the nitrogen and phosphorus requirements for arabica coffee grown in the highlands as well as to compare the effect of chemical fertilizer and farm manure.

Results of the study indicated high requirement of nitrogen at the early stages of growth while the response to phosphate treatment was not observed. Meanwhile, application of phosphate alone resulted in even poorer growth of the plants. Phosphate coupled with nitrogen application helped increasing healthier canopies. The requirement of sufficient nitrogen was still observed in the plants reaching bearing stage. The presence of soil phosphate tended to increase yield. Results of the experment indicated that 24 to 48 g N/plant/year were sufficient for the first year of growth. The rate of application increased as the age of the plants increased (30 to 40 percent increase per year of age.).

Phosphate application at the rate of 30 g P_2O_5/plant/year was sufficient. Repeat application of phosphate for three successive years increased the amount of soil phosphate around the root zone of the coffee plants (7.3 ppm. prior to application Versus 30 to 100 ppm after three years of application.)

At early stage of growth, application of cow manure alone at the rates of 15 to 20 kg/plant/year gave similar or even better results when compared to those receiving nitrogen application alone. As the coffee plants reaching bearing stage, application of cow manure alone was not sufficient.

E. Study on the effect of nitrogen, and potassium fertilizers on arabica coffee.

The objectives of the study were to confirm the essentiality of nitrogen for coffee plant growth in location where soils is different from the previous study. The effect of potassium as related to nitrogen was also studied.

Results of the study confirmed the essentiality of nitrogen for vigorous growth of coffee plants in the first three years of age. The rate of application was 20 g/plant/year on the year and a 30 percent increase of the rate per increased year of

age was sufficient. The response to potassium application and its correlation with nitrogen was still not observed.

F. Study on the propertiming of fertilizer application for arabica coffee.

Proper chemical nutrient elements and their proper ratio are not the only mean in increasing yield of arabica coffee. Proper timing of the fertilizer application could be equally important since up-proper timing of fertilizer application could result in the loss of the nutrients through leaching, fixing by clay particles and becomes unavailable to the plants or eroded with the surface run-off. Besides, un-proper timing application could be ineffective since the plants might not be at the stage of needing such elements.

Results of the study indicated no difference among the application treatments made in March, April and May. However, the May application with follow up treatments in 4 to 5 months tended to be a more appropriate time of fertilizer application.

G. Varietal and fertilizer trial.

Chemical fertilizers have proved to be essential to the growth of coffee plants grown under the highland conditions of Northern Thailand. Under specific conditions, specific varieties may respond differently to specific treatments. The objectives to chemical fertilizer treatments.

Results of the study indicated no significant response of a particular variety to the chemical treatments. However the variety Villa lobos tended to respond best to the treatment 10-10-20.

Summary Page

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Agronomic, Pathological and Entomological Reserch on *Coffea arabica* as a Replacment Crop for Opium Poppy in the Highlands of Thailand.

Investigations on agronomic, Pathological and Entomological aspects of *Coffea arabica* were initiated in 1974. The objectives of the investigations were to introduce, evaluate and establish arabica coffee as a replacement crop for opium poppy in the highlands of Northern Thailand. The first phase of the investigations was ended in June, 1977 and the project was extended for its second phase. In the second phase, particular attention was given to variety testing and screening for rust resistance. As the project ended its second phase in 1980, many aspects of the investigations are still far from conclusion. Nevertheless, continuation of the investigations will be carried on by the Department of Agriculture.

Identification of the physiologic races of leaf rust present in the different coffee growing areas in the highlands of Northern Thailand is very important. The information can be used as a key leading to the screening of rust resistant varieties specifically adapted to the highland conditions of Thailand. In so far, the physiologic races II and III have been identified. Basing on leaf rust resistance, high yielding, acceptable bean quality and adaptability to the highland conditions, the *C. arabica* varieties Catura and Catuai are recommended for planting without shading. Meanwhile, *C. arabica* varieties K7, DK 1-6, S.288, S.795 and S.1934 are recommended for planting with shading.

Proper cultural practices would ensure a successful cultivation. These included the appropriate kind and quality of seedlings at the time of planting, land and planting hole preparation, appropriate time of planting, care and management of young seedlings, fertilizer application and spraying program. Multiple stem of pruning system proved to be superior to single

stem system and rejuvenation of declined plantations was feasible.

on the pathological aspects, technique on the artificial inoculation of leaf rust has been developed and proved to be helpful to the identification of rust resistant clones collected from the various mother plants grown in the various regional mother plant collections. Under the variety reaction study, rust resistant clones were identified. They were then transported into the fields at different growing sites in the highlands. Offsprings of these plants will be tested again for their rust resistance and those with possitive results will be released as resistant varieties specifically adapted to the highland conditions of Thailand.

Chemical control measures on both pathological and entomological aspects were undertaken. Results of the studies have been put into the plant protection program recommended for the areas where the extension of arabica coffee as a replacement crop for opium poppy was carried out.

Investigations on many aspects of the mineral nutrition undertaken. Results of the investigations have been used as guide lines in the extension of arabica coffee to the highlands. The results can also be used as basic information for future research works.